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5 GHz 200 Mbit/s Radio Over Polymer Fiber Link with Envelope Detection at 650 nm Wavelength

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Abstract: All-optical envelope detection of a 5 GHz 200 Mbit/s modulated RF signal and error free transmission over 50 m POF link is achieved by using a 650 nm RCLED.

OCIS codes: (060.4510) Optical communications; (060.5625) Radio frequency photonics

1. Introduction

Polymer optical fibers (POF) are considered a promising transmission medium for short range broadband communications links such as in-home networking scenarios. POF are flexible and robust compared to their silica counterparts and have a large mode-field diameter, which enables easy coupling to light sources and detectors, thereby facilitating the use of a do-it-yourself approach to installation [1, 2].

Polymetyl–methacrylate (PMMA) POF typical transmission windows are in the visible region, such as 530, 570 and 650 nm wavelength [2], where low-cost sources are available. Coupling and connectors are less restrictive due to large core size, decreasing overall cost too. On the other hand, high attenuation of about 200 dB/km limits links to hundreds of meters.

The 650 nm spectral region is an attractive choice due to the visibility of light for reason of security and the availability of low cost light sources and photodiodes. Transmission of baseband signals up to 220 Mbit/s over 50 m long POF have been reported [1,2]. However, with the increasing requirements for high capacity and mobility, a POF based backbone in-home networks will need to support transport of signals destined both for wireless and wireline terminals, increasing network flexibility. Current light sources, photodectors and POF links operating at 650 nm suffer from bandwidth and dispersion limitations preventing transmission of high carrier frequencies such as 2.5 GHz or 5 GHz needed for wireless communication links [3].

In this paper, we propose and experimentally demonstrate transmission and all-optical envelope detection of a 200 Mbit/s signal modulated on a 5 GHz RF carrier, by taking advantage of resonant cavity light emitting diode (RCLED) characteristics as demodulator. Error-free performance was achieved after transmission over a 50 m POF link at a wavelength of 650 nm. The fiber used was a graded index PMMA fiber with a core diameter of 1 mm. The key enabling technique is the use of the electrical modulation properties of the RCLED to act as a halfwave rectifier and low pass filter.

The electro-optical response of the RCLED is shown in figure 1. For driving currents below zero, no light is emitted, therefore the electrical signal is rectified in the optical medium. For a small values of the driving current (< 25 mA) of the modulation response behaves linear but as larger driving current values can distort the optical signal. The limited frequency response of the RCLED up to 125 MHz results on low-pass filtering of the input signal. The device is designed for fast-Ethernet signals up to 125 Mbit/s, being unable to follow the high carrier RF frequency in the Gigahertz range.

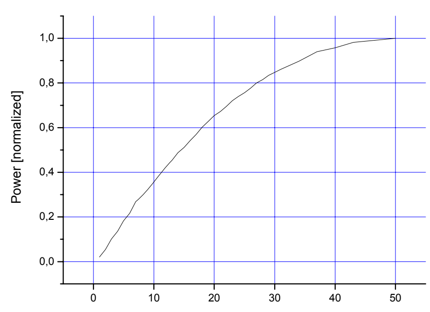

Fig 1: Electro-optical response of the RCLED (normalized)

In this way, envelope detection of a wireless signal [4] is performed and imposed directly onto a 650 nm optical carrier by directly modulating the RCLED and therefore it is transmitted at baseband over the POF link, avoiding at one hand the use of local oscillators for frequency downcoversion and on the other hand exploiting baseband transmission instead of high frequency signal transport over the POF link.

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2. Experimental setup

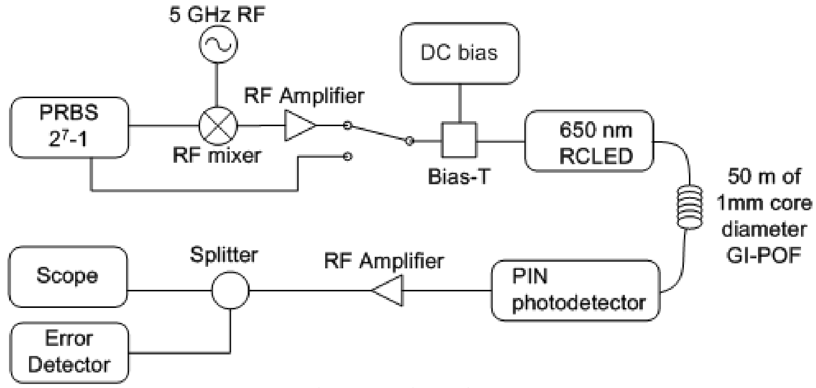


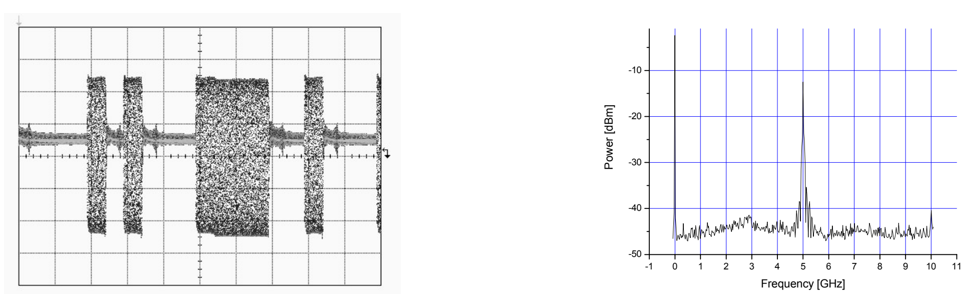
Fig. 2: Experimental setup.

Figure 2 shows the experimental setup used in our demonstration. The baseband signal is a non-return-to-zero (NRZ) pseudo random binary sequence (PRBS) with a pattern length of 2^7-1. The bit rate was varied from 100 to 220 Mbit/s. This signal was used either to modulate the RCLED or to amplitude modulate a 5 GHz carrier using RF mixer. For the case of a RF modulated signal, electrical amplification was used due to the limited output power of the RF mixer. A bias-T was used to apply a DC biasing current. The RCLED is coupled to a 1mm diameter graded index GI POF from Fiberfin®.

At the receiver side, a photodiode, designed for operation at 650 nm wavelength was used. The measured value of the attenuation of the fiber was 9 dB for the 50 meter POF link, which leads to 180 dB/km at the experiment wavelength. The specified data sheet bandwidth for the RCLED and photodiode is 125 Mbps, compliant with Fast Ethernet transmission. The minimum optical power available at the output of the RCLED was measured to be -8.5 dBm whereas the receiver sensitivity of the receiver is specified to be -24 dBm according to the vendor's data sheet, having enough power budget for proper detection.

3. Results

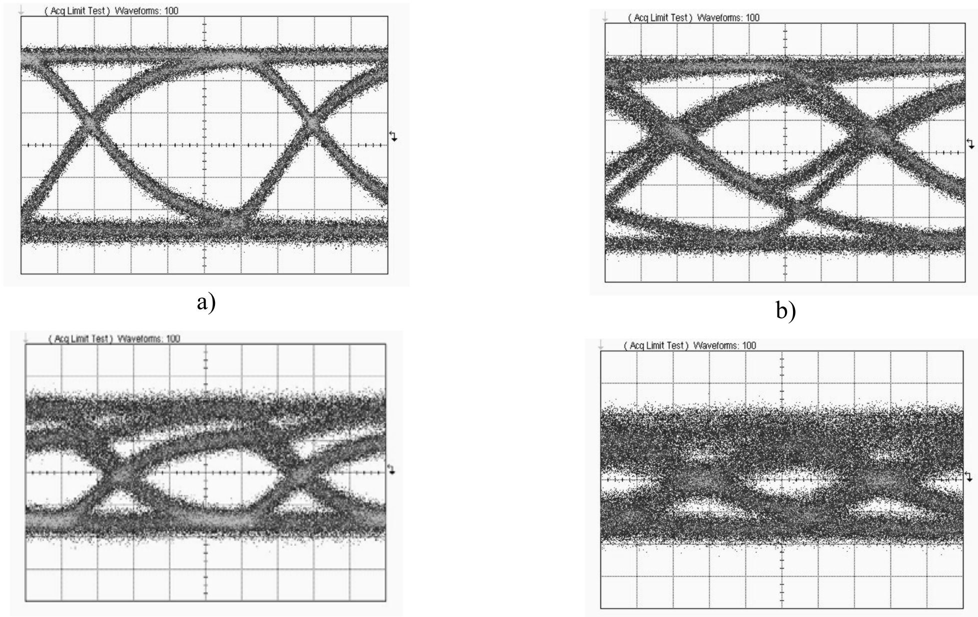
We studied the case for the modulated 5 GHz signal. An example of a pulse pattern and its measured RF spectrum is shown in figure 3 a) and b), respectively. The measured eye diagram shown in Figure 4 c) and d) demonstrates that envelope detection is successfully achieved. Also the performance for baseband transmission was analyzed. The DC bias operating point for the RCLED was set to 12 mA to exploit the linear region of the RCLED modulation curve. We used a bit-error rate tester (BERT) to assess the bit-error rate.



a) b)

Fig 3: Example of a bit pattern of the modulated 5 GHz RF signal a) 100 Mbit/s. Time scale: 20 ns/div b) Measured RF spectrum

Error free transmission was achieved for baseband bitrates from 100 Mbit/s up to 240 Mbit/s over a 50 m long POF link. Measured examples for the eye diagrams are shown in figures 4 a) and b), for 100 Mbit/s and 180 Mbit/s bitrates after 50 m POF transmission. The degradation of the eye shown in figure 4 b) is due to limited response of the RCLED at high frequencies. However, the eye diagram is still wide open and it was still possible to achieve error-free performance. Upon an increase of the link length from 50 m to 100 m, a BER of 2.510^{-5} for a bit rate of 100 Mbit/s was measured. We attribute the limited BER performance due to both the insufficient power budge and the increased modal dispersion.



a) b) c) d)

Fig 4: Measured eye diagram for baseband (left) and envelope detected signal all optical downconverted from 5 GHz (right) for different bitrates, 50 m of 1mm PMMA-GI-POF.
a) 100 Mbit/s. Time scale: 1.654 ns/div b) 180 Mbit/s. 1 ns/div c) 100 Mbit/s. 2 ns/div d) 200 Mbit/s. 1 ns/div

Similarly to the case of the baseband signal transmission, proper demodulation and error-free performance was achieved for bit rates varied from 100 Mbit/s, figure 4 c), up to 220 Mbit/s, figure 4 d). A BER equal to $1x10^{-8}$ was measured after 50 m POF transmission at 220 Mbit/s and indicates again the bandwidth limitation due to the RCLED modulation speed. Comparing the baseband and RF-demodulated signals, it is observed that the driving current should not drive the RCLED into its non-linear region to avoid signal distortions, however, this leads to scarifying the power level for the resultant downconverted "ones" bits and in a lower averaged optical power output.

4. Conclusion

We have experimentally demonstrated a low complexity radio over polymer fibre link operating at the 650 nm wavelength region. A transmission length of 50 m over 1 mm core diameter POF is achieved supporting bit rates up to 200 Mbit/s on a 5 GHz RF carrier making POF based links an attractive solution for wired communication and wireless signal reception in in-door networking scenarios, by using the same low-cost device.

5. Acknowledgements

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